EXHIBIT P

OMNIBUS BROWN DECLARATION

Multicountry, Multifactor Tests of the Factor Abundance Theory

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The Heckscher-Ohlin-Vanek model predicts relationships among industry input requirements, country resource supplies, and international trade in commodities. These relationships are tested using data on twelve resources, and the trade of twenty-seven countries in 1967. The Heckscher-Ohlin propositions that trade reveals gross and relative factor abundance are not supported by these data. The Heckscher-Ohlin-Vanek equations are also rejected in favor of weaker models that allow technological differences and measurement errors.

The Heckscher-Ohlin (H-O) hypothesis is most widely understood in its two-good, two-factor form: a country exports the commodity which uses intensively its relatively abundant resource. Tests of this hypothesis have been inconclusive for two reasons. First, the three pairwise comparisons required by this two × two model cannot be made unambiguously in a multifactor, multicommodity world. Most previous papers that claim to present tests of the hypothesis have used intuitive but inappropriate generalizations of the two×two model to deal with a multidimensional reality. Second, the H-O hypothesis is a relation among three separately observable phenomena: trade, factor input requirements, and factor endowments. A proper test of the hypothesis requires measurements of all three of these variables. Much prior work that claims to have tested the hypothesis has used data on only two of the three hypotheticals.

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This paper reports conceptually correct tests of the H-O hypothesis as suggested by Edward Leamer (1980) and Leamer and Harry Bowen (1981). We use a valid multidimensional extension of the two × two model known as the Heckscher-Ohlin-Vanek (H-O-V) theorem, which equates the factors embodied in a country's net exports to the country's excess supplies of factor endowments. And we use separately measured data on trade, factor input requirements, and factor endowments to conduct the first systematic and complete evaluation of the relationships implied by the H-O-V hypothesis among these three sets of variables.

Our methods contrast sharply with traditional approaches to testing the H-O hypothesis. The classic test of the H-O hypothesis is Wassily Leontief's (1953), which compares the capital per man embodied in a million dollars worth of exports with the capital per man embodied in a million dollars worth of imports. Leamer (1980) shows this comparison does not reveal the relative abundance of capital and labor in a multifactor world. Moreover, Leontief's study uses data on trade and factor input requirements but not factor endowments and, in addition, his data are only for a single country.

A second type of purported test uses a regression of trade of many commodities on their factor input requirements for a single country (for example, Robert Baldwin, 1971; William Branson and Nicholas Monoyios, 1977; Jon Harkness, 1978, 1983; Robert Stern and Keith Maskus, 1981). If the estimated coefficient of some factor is posi-

TABLE 1—RATIO OF ADJUSTED NET TRADE IN FACTOR TO NATIONAL ENDOWMENT

Country	Capital	Labor	Prof/Tech	Manager	Clerical	Sales	Service	Agriculture	Production	Arable	Forest	Pasture
Argentina	1.32	−0.30	−1.64	−2.60	−1.07	−0.62	−0.83	4.30	−1.46	21.24	−6.94	2.40
Australia	−3.77	−0.41	−2.95	−1.79	−1.68	0.21	−0.11	18.10	−3.65	17.15	−13.68	0.80
Austria	−2.03	3.01	2.74	5.64	2.91	3.81	3.20	3.12	2.59	−80.74	13.52	24.35
Bene-Lux	−2.36	1.81	0.88	1.82	1.90	1.36	2.39	−4.26	2.76	−364.25	−922.53	53.27
Brazil	−5.54	−0.27	−0.85	−0.49	−0.82	−0.32	−0.23	−0.04	−0.61	2.10	−0.04	−0.02
Canada	1.82	−3.49	−3.40	−2.23	−4.00	−2.73	−1.88	4.00	−6.84	12.13	6.16	2.84
Denmark	−4.89	5.82	2.37	8.70	4.25	5.08	4.51	24.56	1.21	33.57	803.73	1763.42
Finland	4.69	2.14	0.49	4.22	1.78	1.94	1.89	1.26	3.21	−24.44	30.48	434.70
France	−4.07	0.82	0.70	1.17	1.02	0.90	1.06	0.16	1.04	−21.33	−198.68	1.79
Germany	−1.05	−0.43	1.01	1.34	0.51	−1.08	−1.05	−11.86	2.07	−323.61	−377.64	−124.77
Greece	−5.50	2.93	4.48	14.95	5.37	4.49	4.68	2.20	2.02	46.92	−61.16	1.08
Hong Kong	−46.06	4.52	5.24	3.68	8.10	3.48	3.03	−14.19	6.46	−21568	−30532	−91627216
Ireland	−1.93	6.73	4.49	13.84	7.19	6.10	8.07	10.59	2.67	17.31	−129.98	72.68
Italy	−7.03	0.74	1.25	4.67	1.42	0.39	1.27	−1.73	1.87	−39.91	−431.67	−131.90
Japan	−5.47	0.10	0.44	0.48	0.33	−0.05	−0.03	−1.54	1.18	−341.42	−268.58	−1998.58
Korea	−30.51	0.61	1.53	2.85	1.81	0.76	1.73	0.27	0.85	−42.34	−29.42	1206.60
Mexico	−0.78	0.57	0.19	0.47	0.51	0.80	0.70	0.87	−0.21	12.40	5.69	0.97
Netherlands	−4.56	4.61	3.49	6.36	3.65	4.72	5.53	22.78	1.41	82.74	−719.88	330.86
Norway	−5.54	5.57	3.75	6.15	7.98	10.22	10.58	14.59	−0.06	−125.48	105.96	660.35
Philippines	−13.94	−0.10	−0.59	−0.36	−0.81	0.03	0.06	0.14	−0.81	10.47	−8.43	−17.03
Portugal	−10.31	1.92	3.92	10.85	3.75	2.83	2.72	0.63	2.49	−28.46	24.79	12.03
Spain	−6.19	3.04	4.56	13.88	4.36	4.13	3.89	2.45	2.23	−2.74	−12.00	4.92
Sweden	0.79	1.36	0.59	2.26	1.05	1.09	1.44	−0.66	2.18	−67.23	30.93	48.00
Switzerland	−5.72	3.42	4.46	11.57	3.52	5.42	4.13	−0.79	3.04	−862.95	−352.36	−12.18
UK	−12.86	0.63	1.77	2.04	1.37	1.30	1.32	−18.57	1.11	−313.42	−2573.99	−91.89
US	0.08	−0.25	0.23	−0.11	−0.19	−1.10	−0.68	1.54	−0.34	19.45	−23.82	−1.63
Yugoslavia	−3.15	0.68	0.39	1.59	1.12	2.05	1.15	0.46	0.76	−0.08	2.81	14.24

Note: Numbers in percent. Factor content data are for 1967; endowment data are for 1966.

factor k exceeds the adjusted net exports by country i' of factor k, $(F^A_{ki}/E_{kw})/(Y_i/Y_w) > (F^A_{ki'}/E_{kw})/(Y_{i'}/Y_w)$, if and only if country i is more abundant in factor k than country i', $(E_{ki}/E_{kw})/(Y_i/Y_w) > (E_{ki'}/E_{kw})/(Y_{i'}/Y_w)$. More generally, for each country and factor, the ranking of adjusted net factor exports F^A_{ki}/E_{kw} should conform to the ranking of factors by their abundance. This rank proposition is tested for each country (factor) by computing the Kendall rank correlation between corresponding columns (rows) of the matrix of adjusted factor content and the matrix of factor abundance ratios. In addition, we compute the proportion of correct rankings when the corresponding elements of the columns (rows) of the two matrices are compared two at a time.[6]

Table 1 summarizes the factor content data by listing for each country the ratio of adjusted net exports of each factor in 1967 to the endowment of the corresponding factor in 1966, $100 \times F^A_{ki}/E_{ki}$. According to these data, the United States exports .08 percent of the services of its capital stock, .23 percent of the services of its professional/technical workers but imports labor services amounting to .25 percent of the services of its labor force. Thus, among these resources, U.S. trade reveals the United States to be most abundant in professional and technical workers, capital, and then labor. Among all resources, however, the United States is revealed most abundant in arable land, followed by agricultural workers.

Leamer (1980) computed these factor content ratios using Leontief's 1947 data and found that U.S. trade revealed the United

[6]Subsequent tests of the rank and sign propositions based on the proportion of "successes" do not refer to any specific alternative hypothesis and thus leaves unclear the choice of significance level. Without knowing the proportion of successes expected under a specific alternative hypothesis, judging the relative performance of the H-O-V model is largely impressionistic. The absence of alternative hypotheses when testing the sign and rank propositions is, in large part, the motivation for our subsequent tests of the H-O-V equations in a regression framework.

States to be abundant in capital compared to labor, thus reversing Leontief's paradoxical finding. Likewise, no "Leontief paradox" is evident in Table 1 since the United States exports capital services but imports labor services, and this ordering conforms to the ordering of the U.S. shares of world capital (41 percent) and world labor (22 percent). This result, and others like it, would lead us to accept the H-O theorem on the basis of a rank test.

Although a rank test supports the two-factor version of the H-O theorem for the United States, a contrary finding is that while the United States is a net exporter of capital services, the U.S. share of world income (47 percent) exceeds its share of world capital, which implies that there is a measured scarcity of capital in the United States. This result, and others like it, would lead us to reject the H-O theorem using a sign test.

Some obvious anomalies in Table 1 are that, after adjusting for trade imbalances, Denmark, Finland, Korea, the Netherlands, and Norway export more than 100 percent of the services of their pastureland. These anomalies probably reflect difficulties in applying U.S. input-output coefficients to other countries. For example, Denmark is a substantial exporter of agricultural products and U.S. input coefficients apparently overstate the amount of pastureland used per unit of output in Denmark. The analysis conducted in Section III will formally test the assumption of identical input coefficients, but it is clear from the anomalies in Table 1 that assumption (A3) is not entirely accurate.[7]

Formal tests of the conformity of the adjusted net factor export data (F_{ki}^{A}/E_{kw}) with the factor abundance data $[(E_{ki}/E_{kw})/(Y_i/Y_w)-1]$ are reported in Tables 2 and 3. The first column of Table 2 lists the proportion of sign matches between adjusted net factor exports and the abundance ratios for each factor. The first column of Table 3 lists comparable percentages for each country. For example, the sign of adjusted net capital exports and of excess capital shares matched in 52 percent of the countries.

TABLE 2—SIGN AND RANK TESTS, FACTOR BY FACTOR

Factor	Sign Test[a]	Rank Tests[b]	
Capital	.52	0.140	.45
Labor	.67	0.185	.46
Prof/Tech	.78	0.123	.33
Managerial	.22	−0.254	.34
Clerical	.59	0.134	.48
Sales	.67	0.225	.47
Service	.67	0.282[c]	.44
Agricultural	.63	0.202	.47
Production	.70	0.345[c]	.48
Arable	.70	0.561[c]	.73
Pasture	.52	0.197	.61
Forest	.70	0.356[c]	.65

[a] Proportion of 27 countries for which the sign of net trade in factor matched the sign of the corresponding factor abundance.

[b] The first column is the Kendall rank correlation among 27 countries; the second column is the proportion of correct rankings out of 351 possible pairwise comparisons.

[c] Statistically significant at 5 percent level.

In general, the proposition of conformity in sign between factor contents and excess factor shares receives relatively little support when tested for each factor (Table 2). Although the proportion of sign matches exceeds 50 percent for eleven resources, the proportion of sign matches is 70 percent or greater for only four of the twelve factors with the highest proportion of sign matches for professional and technical workers (78 percent). Moreover, using Fisher's Exact Test, the hypothesis of independence between the sign of the factor contents and of the excess factor shares can be rejected (results not shown) at the 95 percent level for only one resource—arable land.

Similar results are obtained when the sign proposition is tested for each country (Table 3). The proportion of sign matches exceeds 50 percent for 18 countries, and exceeds 90 percent for five countries (Greece, Hong Kong, Ireland, Mexico, and the UK). However, the proportion of sign matches is below 70 percent for 19 of the 27 countries. In addition, the hypothesis of independence

[7] These anomalous data values may also reflect errors of measurement in either the factor contents or endowments. In particular, Denmark and Norway probably export more than 100 percent of their forestland because these countries export fish and fish products, and fisheries are included in the input-output coefficients for forestland.

TABLE 3—SIGN AND RANK TESTS, COUNTRY BY COUNTRY

Country	Sign Tests[a]	Rank Tests[b]	
Argentina	.33	0.164	.58
Australia	.33	−0.127	.44
Austria	.67	0.091	.56
Belgium-Luxembourg	.50	0.273	.64
Brazil	.17	0.673[c]	.86
Canada	.75	0.236	.64
Denmark	.42	−0.418	.29
Finland	.67	0.164	.60
France	.25	0.418	.71
Germany	.67	0.527[c]	.76
Greece	.92	0.564[c]	.80
Hong Kong	1.00	0.745[c]	.89
Ireland	.92	0.491[c]	.76
Italy	.58	0.345	.69
Japan	.67	0.382	.71
Korea	.75	0.345	.69
Mexico	.92	0.673[c]	.86
Netherlands	.58	−0.236	.38
Norway	.25	−0.236	.38
Philippines	.50	0.527[c]	.78
Portugal	.67	0.091	.56
Spain	.67	0.200	.62
Sweden	.42	0.200	.62
Switzerland	.67	0.382	.69
United Kingdom	.92	0.527[c]	.78
United States	.58	0.309	.67
Yugoslavia	.83	−0.055	.49

[a] Proportion of 12 factors for which the sign of net trade in factor matched the sign of the corresponding excess supply of factor.

[b] The first column is the Kendall rank correlation among 11 factors (total labor excluded); the second column is the proportion of correct rankings out of 55 possible pairwise comparisons.

[c] Statistically significant at the 5 percent level.

between the classification of signs is rejected (95 percent level) for only four countries: Greece, Ireland, Hong Kong, and the United Kingdom.[8] Finally, for the entire sample, the proportion of sign matches out of a possible 324 is only 61 percent.

The sign proposition deals with the abundance of a resource compared with a value-weighted average of other resources (that is, Y_i/Y_w), but we can also compare resources two at a time. For example, the data in Table 1 indicate the United States is more abundant in capital than labor while the U.S. resource share data (not shown) also indicate an abundance in capital compared to labor. The many possible pairwise comparisons are summarized by the rank proposition, which states that the order of adjusted factor contents and the order of the resource abundance ratios conform.

Two formal measures of the conformity between the factor content and factor abundance rankings are shown in Tables 2 and 3. The second column in these tables shows the Kendall rank correlation between the rankings while the third column shows the proportion of correct orderings when the comparisons are made two at a time.[9] For example, the results for capital in Table 2 indicate that we cannot reject (5 percent level) the hypothesis of a zero-rank correlation and that the proportion of correct orderings when the ranking between the net exports of capital services and the capital abundance ratios is compared for all pairs of countries is 45 percent.

In general, the rank proposition receives little support when tested for each factor (Table 2). The hypothesis of a zero-rank correlation is rejected (95 percent level) for only four resources (service workers, production workers, arable land, and forestland) and one of the correlations (managerial workers) is of the wrong sign. Little support is also found for the rank proposition when the comparisons are made among all possible pairs of countries. Specifically, the proportion of correct orderings exceeds 50 percent only for the three land variables.

The rank proposition also receives little support when tested country by country (Table 3). The hypothesis of a zero-rank correlation is rejected for only eight of the 27 correlations (95 percent level) and five of the correlations are of the wrong sign. Somewhat greater support is found for the rank proposition when pairwise comparisons are considered: for 22 of the 27 countries, the proportion of correct orderings exceeds 50 percent. That the rank proposition re-

[8] No variation was observed in the sign of factor abundance for Yugoslavia (each was positive).

[9] These proportions are interpreted as the probability, for a given factor (country), that the ranking of factor contents will match the ranking of factor abundance for a randomly selected pair of countries (factors).

ceives relatively more support when tested country by country suggests that something is affecting all the data similarly, since adding a number that is constant within a country would not affect the country rank test results but would alter the other three tests. A possible source of this kind of problem would be differences in factor input matrices across countries.

Overall, the results for the sign and rank propositions offer little support for the H-O-V model. However, the tests of these propositions do not refer to specific alternative hypotheses and may cast doubt on the H-O-V hypothesis for a variety of reasons, including nonproportional consumption, various kinds of measurement error, and differences in factor input matrices. These alternatives can be studied by regressions of factor contents on endowments as described below.

III. Tests of the H-O-V Equations

The tradition since Leontief's study has been to examine only propositions concerning factor rankings. But as shown in Section I, the H-O-V model actually implies an equality between factor contents and resource supplies. A study of this system of equations has the advantage that it allows explicit consideration of alternative hypotheses—a practice that has generally been absent in empirical tests of trade theory. Here we consider three reasons why the H-O-V equations may be inexact: nonproportional consumption, measurement errors, and technological differences.

A. *Alternative Hypotheses*

We first consider an alternative to the assumption of proportional consumption (A2). The general hypothesis of nonidentical, nonhomothetic tastes cannot be allowed since then trade, which is the difference between production and consumption, would be completely indeterminate.[10] Instead, we study a specific alternative to assumption A2:

($\tilde{A}2$) *All individuals have identical preferences with linear Engel curves; within each country, income is equally distributed.*

The modification of (4) implied by ($\tilde{A}2$) is derived by noting that ($\tilde{A}2$) implies that per capita consumption is a linear function of per capita income. Therefore, we can write country i's total consumption of commodity j (C_{ij}) as a linear function of its population L_i and its total expenditure $(Y_i - B_i)$:[11]

$$(7)\quad C_{ij} = \lambda_j L_i + \psi_j\left((Y_i - B_i) - L_i y^0\right),$$

where λ_j = per capita "autonomous" consumption of commodity j,

ψ_j = marginal budget shares, $\sum_j \psi_j = 1$,

$y^0 = \sum_j \lambda_j$.

Summing (7) over i gives the marginal budget shares ψ_j:

$$(8)\quad \psi_j = \left(Q_{wj} - \lambda_j L_w\right)/\left(Y_w - L_w y^0\right),$$

where L_w is world population. Inserting (8) into (7) and premultiplying by the kth row of $\mathbf{A}(\mathbf{a}_k)$, the amount of factor k absorbed in consumption $\mathbf{a}_k\mathbf{C}_i$ is

$$(9)\quad \mathbf{a}_k\mathbf{C}_i = \left(\varphi_k - \beta_k y^0\right)L_i + \beta_k Y_i,$$

where

$$\varphi_k = \sum_j a_{kj}\lambda_j,$$

$$\beta_k = \left(\sum_j a_{kj}Q_{wj} - \sum_j a_{kj}\lambda_j L_w\right)/\left(Y_w - L_w y^0\right),$$

$$\beta_k = \left(E_{kw} - \varphi_k L_w\right)/\left(Y_w - L_w y^0\right).$$

[10] In the sense that complete information on each country's preferences would be required to determine trade.

[11] Equation (7) is based on the Linear Expenditure System.